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Effect of Optimal Area and Mineral Feed Level on Obtaining High Yields of Malting Barley

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Abstract

The purpose of this study was the scientific justification for obtaining high yields of malting barley of the Grace variety based on the optimal area and mineral level. The objective of the study was to evaluate the change in the completeness of germination, preservation, and survival of plants resulting from mineral nutrition and the nutrition area and to establish the growth, development, and change in the elements of the crop structure and yield depending on the use of mineral fertilizers ($N_{30}P_{30}K_{30}$, $N_{60}P_{60}K_{60}$) and nutrition area. Considering the agro-climatic resources of the southeast of the forest-steppe in the Non-Chernozem region and the biological features, the authors developed methods for realizing the productive potential of malting barley of the Grace variety. A two-factor field experiment was set in 2016, 2018, and 2019. Rational doses of mineral fertilizers and seeding rates in the technology of cultivation of multi-row barley are determined. The paper presents the results of studies on the complex effect of the background of mineral nutrition and the area of nutrition on the density, completeness of germination; preservation, survival of plants; elements of the crop structure, and grain yield of malting barley of the Grace variety on leached chernozems of the Republic of Mordovia (Russia). It is established that the highest grain yield (3.84 t/ha) is provided when mineral fertilizers are applied at the rate of $N_{60}P_{60}K_{60}$ and the seeds are sown at a norm of 5.0 million germinating seeds per ha.

Keywords: Fertilizers; Seeding rates; Safety and survival of plants; Grain yield.

1. Introduction

One of the main field crops in the Republic of Mordovia (Russia) is barley, which is cultivated for food, fodder, and brewing purposes. It is economically more efficient to use it as a raw material for the brewing industry. For these purposes, many varieties have recently been recommended. It is very important to know how certain elements of technology (area and level of mineral nutrition) affect the growth, development, yield, and quality of grain in specific soil and climatic conditions of new varieties of intensive type.

Obtaining good yields of high-quality grain crops, including barley, depends on soil and climatic conditions [1, 2]. In the modern world, in the period of aggravation of the economic and energy crisis, progressive technologies of crop cultivation should guarantee significant yields. Modern technologies of barley cultivation should use both mineral fertilizers and bio- and humic preparations, new generation growth regulators with a wide range of physiological activity, capable of coordinating, stimulating, or inhibiting various processes in plants, as well as their combinations [3-6].

In the formation of barley yield, the share of the influence of mineral fertilizers ranges from 25 to 80%. Their proper use contributes to an increase in yield, grain quality, and plant resistance to drought, diseases, and pests [7].

The use of the $N_{90}P_{90}K_{90}$ fertilizer provided a preferential increase in grain yield and was economically feasible in Mordovia on chernozems leached for multi-row barley of the Tandem variety [8].

In the Razdolye LLC of the Kolyshleysky district of the Penza region, the introduction of $N_{45}P_{50}$ solid fertilizers with the rate of application equaling kg/ha on leached chernozems contributed to an increase in the yield of barley grain of the Volgar variety by 15.3%, and the Odessa 100 variety by 16.1%. The weight of 1,000 grains increased by 4.9 and 4.7% [9, 10].

In the Republic of Tatarstan, studies showed that the application of mineral fertilizers for the planned yield of barley grain of the Timerkan variety equaling 4 t/ha contributed to an increase in yield by 77.1% compared to the control variant (2.36 t/ha, without fertilizers) [11].

On the leached chernozems in the conditions of the forest-steppe of the Middle Volga region, the use of NARGO bioorganic fertilizer, as well as $N_{15}P_{15}K_{15}$ and $N_{15}P_{15}KS_{10}$ nitrogen-phosphate-potassium complex fertilizers contributed to an increase in the grain yield of feed barley Nutans 553 by 0.25-0.63 t/ha. The maximum increase in the control variant (21.5%) was provided by the joint use of NARGO with sulfur-containing complex fertilizers [12].

In studies conducted in Mordovia, on leached chernozem with an increase in the seeding rate of Tandem multi-row barley from 3.5 (control variant) to 5.5 million germinating seeds per ha (with an interval of 0.5 million), grain yield (5.80 t/ha) was maximal at the sowing rate of 4.5 million germinating seeds, which was 31.5% higher than the control variant [3].

As follows from the review of sources in various soil and climatic zones, barley varieties have different effects on fertilizers and seeding rates. Therefore, it is important to study the complex effects of mineral fertilizers and seeding rates on the growth, development, and grain yield of malting barley in Mordovia.

The purpose of the study was the scientific justification of obtaining high yields of malting barley of the Grace variety based on the optimal area and mineral feed level.

2. Material and Methods

In 2016, 2018, and 2019, in the instructional farm of the Ogarev Moscow State University (Russia), a two-factor field experiment was set in field No. 5 according to the following scheme: factor A: fertilizer background. 1.1: control variant, without fertilizers. 1.2: $N_{30}P_{30}K_{30}$. 1.3: $N_{60}P_{60}K_{60}$. Factor B: seeding rate. 1.1: 3.5 million germinating seeds per ha (control variant). 1.2: 4.0. 1.3: 4.5. 1.4: 5.0. 1.5: 5.5. The predecessor was winter wheat; sowing dates from May 1 to May 5 at a soil temperature of 6-8°C. The introduction of the indicated doses of fertilizers contributed to an increase in the protein content and amounted to 10.4% in 1.1 control (without fertilizers), 11.01% in 1.2 $N_{30}P_{30}K_{30}$, and 11.02% in 1.3 $N_{60}P_{60}K_{60}$. Growth stimulants were not used.

The experimental work was based on laboratory and field research methods. The object of the study was malting barley of the Grace variety. The protein content in grain varied from 10 to 11%. The area of the plot of the first order (with mineral fertilizers) was 45 m^2 (5 × 9 m^2), the area of the plot of the second order was 9 m^2 (1.8 × 5 m), and their placement was systematic in threefold repetition.

The soil of the experimental site was leached chernozem, of a heavy loamy granulometric composition. The humus content was 6.2%, the pH was 4.8, the mobile phosphorus was 189, the exchangeable potassium was 209 mg/kg of soil; the hydrolytic acidity was 5.4, the sum of exchangeable bases was 29.0 mg eq/100 g of soil; the trace elements content was the following, mg/kg: B: 2.05; Mn: 61; Si: 3.8; Mo: 0.17; Co: 1.5 mg/kg.

Phenological observations (density, completeness of germination, preservation, survival of plants, and crop structure) were determined by the method of the State Variety Network. These accompanying observations helped to determine the factors that influenced the grain yield. The harvest was carried out by continuous accounting. The experiments were laid out, and the data obtained were processed by the method of variance analysis according to R. Fisher using Excel statistical software [13].

For the experiment, we used the agricultural techniques generally accepted for Mordovia, except for the variants under study. Mineral fertilizers were applied in autumn at the time of fall plowing. We used nitrogen-phosphorus-potassium fertilizers ($N_{16}P_{16}K_{16}$). In the spring, we harrowed the fall-plowed land and performed pre-sowing cultivation to a depth of 5-6 cm, ordinary sowing in rows and rolling.

Agrometeorological conditions in the years of the study are presented in Table 1.

Table-1. Agrometeorological conditions in the years of the study

Year	Period	Characteristics	Hydrothermal index (HTI)
2016	from sowing to the emergence of seedlings	acutely arid	0.11
	from germination to tillering	too saturated with water	1.88
	from tillering to stem elongation	normal moisture content	1.04
	from stem elongation to earing	normal moisture content	1.08
	from earing to full ripeness of grain	arid	0.49
	entire growing season	somewhat arid	0.79
2018	from sowing to germination	medium-arid	0.76
	from germination to tillering	acute lack of moisture	0.43
	from tillering to stem elongation	acute lack of moisture	0.33
	from stem elongation to earing	acute lack of moisture	0.53
	vegetative	acute lack of moisture	0.46
	generative	acute lack of moisture	0.54
	from sowing to full ripeness of grain	acute lack of moisture	0.50
2019	from sowing to the emergence of seedlings	insufficient moisture levels	0.82
	from sprouting to tillering	too much moisture	1.51
	from tillering to stem elongation	very arid	0.44
	from stem elongation to earing	sufficiently moist	1.06
	vegetative	insufficiently moist	0.97
	generative	too moist	1.37
	from sowing to full ripeness of grain	normal moisture supply	1.10

3. Results

Our study has established that the timing of the onset of phenological phases and the duration of interphase periods do not change from the studied factors. The growing season of barley in 2016 was 82 days, in 2018 – 87 days, and in 2019 – 86 days.

The use of fertilizers on average in 2016, 2018, and 2019 contributed to an increase in the density of seedlings to 29 pcs/ha (8.1%) (Table 2).

Table-2. The effect of fertilizers and seeding rates on the safety and survival of plants

Factors		**Seedlings**		**Plants**		
fertilizers (factor A)	seeding rates, million/ha (factor B)	density, pcs/m^2	completeness, %	safety %	survival rate, %	the number before harvest, pcs/m^2
No fertilizers (control)	3.0	262	75.1	74.1	55.4	194
	3.5	300	75.1	74.5	55.8	222
	4.0	338	75.2	71.7	52.0	242
	4.5	416	80.4	72.3	58.1	291
	5.0	477	82.7	59.1	48.9	269
Average for the background without fertilizers		359	77.7	70.3	54.0	244
$N_{30}P_{30}K_{30}$	3.0	294	84.0	72.5	57.5	216
	3.5	338	84.5	73.2	58.1	247
	4.0	371	85.5	71.1	55.5	268
	4.5	430	86.1	76.8	61.5	330
	5.0	474	86.2	67.9	53.2	323
Average for the background $N_{30}P_{30}K_{30}$		381	85.2	72.3	57.2	277
$N_{60}P_{60}K_{60}$.	3.0	296	84.7	76.3	62.8	228
	3.5	343	85.2	74.4	63.8	254
	4.0	390	86.6	77.3	60.8	302
	4.5	432	87.1	64.2	59.8	317
	5.0	480	87.4	71.6	54.5	343
Average for the background $N_{60}P_{60}K_{60}$.		388	86.2	72.8	60.3	289
Average for the experiment		376	83.0	71.8	57.2	270
LSD_{05} A		9	1.4	0.8	1.0	4
LSD_{05} B, AB		12	1.8	1.0	1.3	6
LSD_{05} of particular differences		21	3.1	1.8	2.2	9

Note: LSD is the least significant difference.

With an increase in seeding rates, seedling density increased by 68.0%. When considering particular differences, this indicator had an advantage against the background of fertilizers $N_{60}P_{60}K_{60}$ with a seeding rate of 5.0 million seeds per ha. Positive interaction of factors was established.

Fertilizers contributed to an increase in the completeness of germination by 7.5 and 8.5%. It was greatest when sowing with a norm of 4.5-5.0 million seeds per ha. Concerning the particular differences, this indicator had an advantage, compared with the control variant, against the background without the use of fertilizers at a seeding rate of 4.5 and 5.0 million seeds per ha, and the background of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$ in all variants of seeding rates. There was no interaction of factors.

The application of mineral fertilizers contributed to an increase in plant safety by 2.0-2.5%. With an increase in seeding rates from 4.0 to 5.0 million seeds per ha, a decrease in the preservation of 1.1-8.1% was noted. When considering particular differences, it had the greatest significance against the background of $N_{30}P_{30}K_{30}$ and the seeding rate of 4.0 million seeds per ha, compared to the control variant. There was an interaction of factors.

The survival rate of plants was maximal with the use of $N_{60}P_{60}K_{60}$ fertilizers. Its minimum value was noted at a seeding rate of 5.0 million seeds per ha. Here, in the variant without the use of solid fertilizers, it was minimal. Positive interaction of factors was established.

The use of mineral fertilizers contributed to an increase in the number of plants before harvesting by 13.1 and 18.9%. It had an advantage when sowing with a rate of 4.5 and 5.0 million seeds per ha. When considering particular differences, its maximum value was noted with the use of fertilizers at the rate of $N_{60}P_{60}K_{60}$ and sowing with a norm of 5.0 million seeds per ha. Positive interaction of factors was noted.

The number of productive stems increased with the use of mineral fertilizers by 15.1 and 22.5 % and was the maximum against the background of $N_{60}P_{60}K_{60}$ (Table 3).

Table-3. Changes in the structural elements and grain yield depending on fertilizer doses and seeding rates

Factors		Number, pcs/^{m2}		Grain weight per ear, g	Yield of grain, t/ha	Cee
fertilizers (factor A)	seeding rates, million/ha (factor B)	productive stems	grains per ear			
No fertilizers (control)	3.0	257	15.0	0.76	1.97	0.50
	3.5	288	14.4	0.93	2.65	0.52
	4.0	296	14.5	0.77	2.35	0.51
	4.5	352	15.1	0.77	2.60	0.51
	5.0	368	15.2	0.87	3.07	0.52
Average for the background without fertilizers		312	14.8	0.82	2.53	0.51
$N_{30}P_{30}K_{30}$	3.0	283	15.2	0.90	2.52	0.52
	3.5	303	13.2	0.77	2.37	0.55
	4.0	343	15.2	0.80	2.74	0.48
	4.5	420	15.7	0.80	3.43	0.52
	5.0	445	14.0	0.77	3.43	0.53
Average for the background $N_{30}P_{30}K_{30}$		359	14.8	0.81	2.90	0.51
$N_{60}P_{60}K_{60}$.	3.0	290	13.7	0.73	2.22	0.52
	3.5	352	13.3	0.77	2.64	0.55
	4.0	394	13.2	0.77	3.21	0.48
	4.5	416	14.5	0.80	3.37	0.52
	5.0	456	14.9	0.83	3.84	0.53
Average for the background $N_{60}P_{60}K_{60}$.		359	14.7	0.78	3.06	0.53
Average for the experiment		351	14.5	0.80	2.83	0.52
LSD_{05} A		14	0.8	0.05	0.11	6.42
LSD_{05} B, AB		18	1.0	0.06	0.14	8.29
LSD_{05} of particular differences		32	1.8	0.11	0.24	14.4

Note: Cee is the coefficient of economic efficiency (grain ratio to total aboveground biomass).

Their advantage was noted at a seeding rate of 5.0 million seeds per ha. In the same variant against the background of $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$, this indicator prevailed in particular differences. Positive interaction of factors was noted.

The introduction of mineral fertilizers or an increase in seeding rates did not contribute to an increase in ear grain content. A similar pattern was noted for particular differences. The interaction of factors was not noted.

An increase in fertilizer doses and seeding rates did not increase the weight of grain from the ear. When considering particular differences, it had an advantage against an unfavorable background at a seeding rate of 3.5 million seeds per ha, as well as against the background of $N_{30}P_{30}K_{30}$ and a seeding rate of 3.0 million seeds per ha. There was a positive interaction of factors.

The maximum grain yield was obtained against the background of mineral feed with $N_{60}P_{60}K_{60}$. It had an advantage with the seeding rate of 5.0 million seeds per ha. Here, its greatest value was noted when considering particular differences, where it exceeded 94.9% (1.94 times (3.84:1.97)), over the control variant. This was caused by a greater number of productive stems. Positive interaction of factors was noted. The factors under study did not affect the Cee.

4. Discussion

Based on the analysis of available literature data, we established that barley plays an important role in increasing the production of food, technical, and feed grains in the Russian Federation. The main function for growth and development and in increasing productivity and improving the quality of grain belongs to mineral fertilizers and other means of chemicalization [4, 5, 12]. There are opinions about the expediency of sowing barley varieties of intensive type with small seeding rates, provided that they are fully satisfied with nutrients. A strong relationship between biometric indicators and grain yield has been revealed [1].

Our studies revealed the feasibility of applying mineral fertilizers at the rate of $N_{60}P_{60}K_{60}$ and sowing at a rate of 5.5 million germinating seeds per ha of the Grace malting barley on leached chernozems in Mordovia. This contributes to obtaining the maximum grain yield by increasing the number of productive stems and increasing the protein in the grain from 10.4 to 11.02%.

5. Conclusion

Thus, to obtain the highest grain yield in malting barley of the Grace variety on leached chernozems, in Mordovia, it is advisable to apply mineral fertilizers at the rate of $N_{60}P_{60}K_{60}$ and sow a norm of 5.5 million germinating seeds per ha. The maximum yield in this variant is formed due to a larger number of productive stems.

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